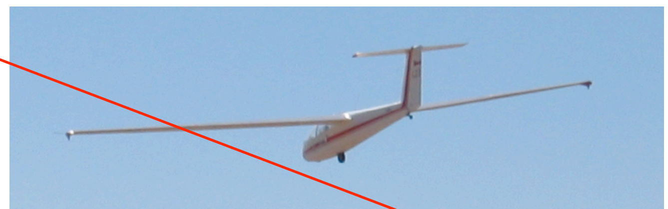
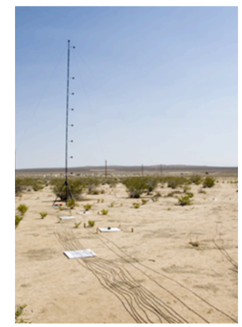
Initial Results from the Variable Intensity Sonic Boom Database

AIAA-2008-3034





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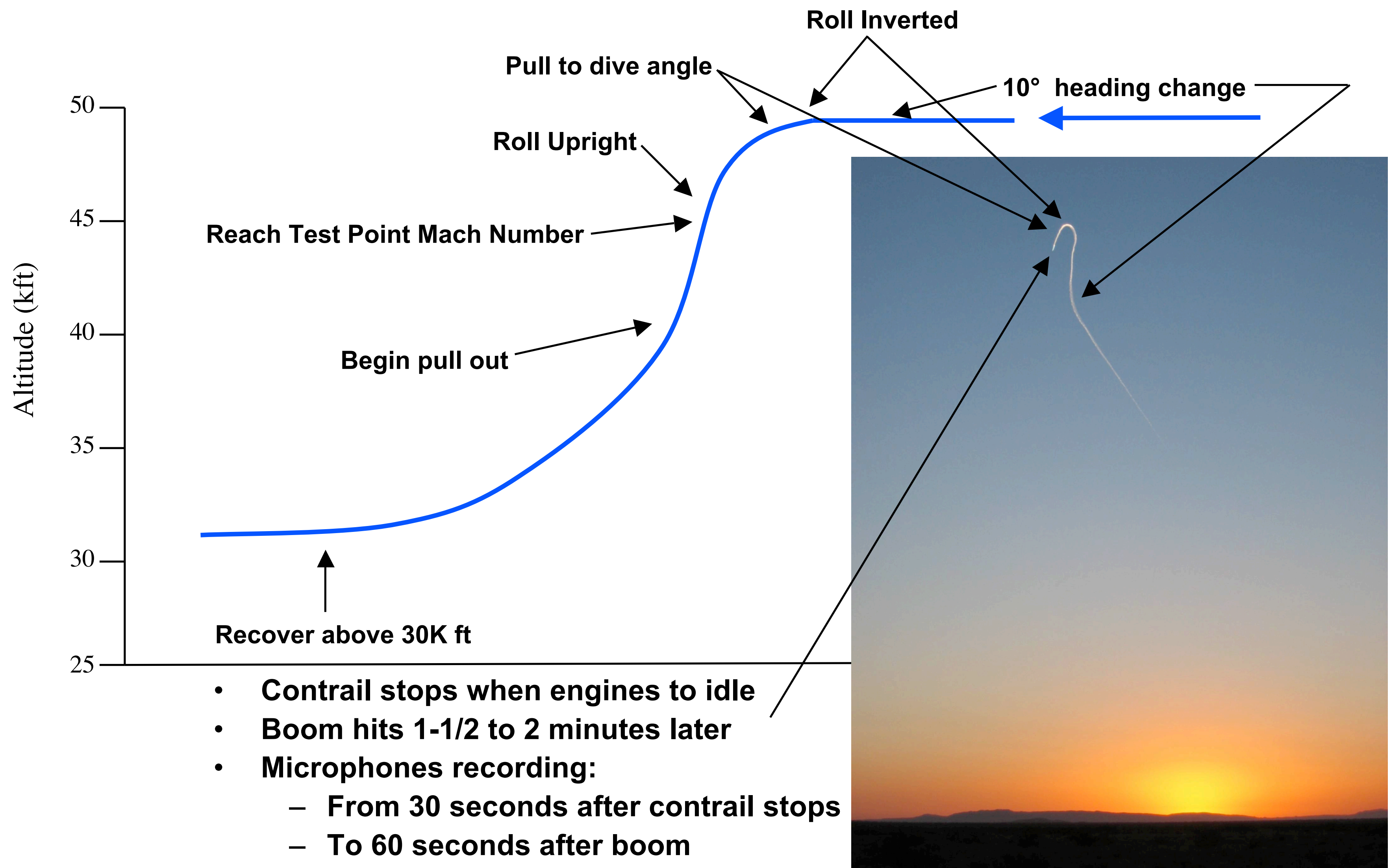
House VIBES (Variable Intensity Boom Effect on Structures)

- **43 sonic booms generated (a few were evanescent waves)**
  - **Overpressures of 0.08 to 2.20 lbf/ft^2**
  - **Risetimes of about 0.7 to 50 ms**
- **Objectives**
  - **Structural response of a house of modern construction**
  - **Sonic boom propagation code validation**
- **Approach**
  - **Measure shockwave directionality**
  - **Determine effect of height above ground on acoustic level**
  - **Generate atmospheric turbulence filter functions**

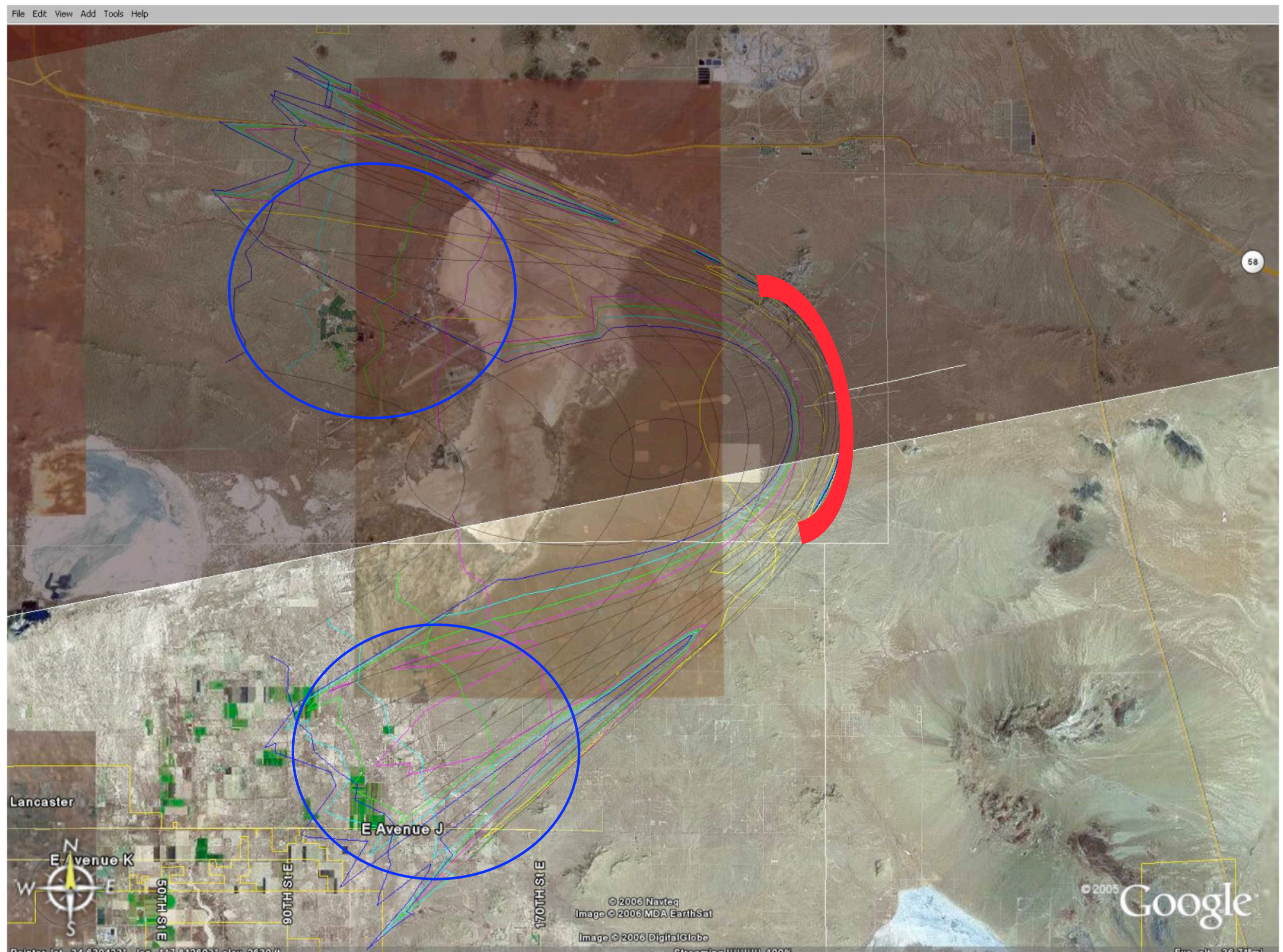
Low Boom Dive Flight Maneuver



- Contrail stops when engines to idle
- Boom hits 1-1/2 to 2 minutes later
- Microphones recording:
  - From 30 seconds after contrail stops
  - To 60 seconds after boom
- Recordings used for boom simulators

Low Boom Dive Footprint

- PCBoom4 calculated footprint on GoogleEarthPro map
  - Preflight GPSsonde weather balloon
  - Aircraft trajectory data
- High overpressure area
- Low Boom area



10m Tower

- 14 Brüel & Kjaer Model 4193 microphones
- Heights of 0, 1.2, 2, 3, 4, 5, 6, 7, 8, and 10m
- Lateral ground microphones at 5 and 10m south and east
- All data digitally sampled simultaneously at 24,000 sps or higher
- 24-bit resolution
- GPS based IRIG-B timecode

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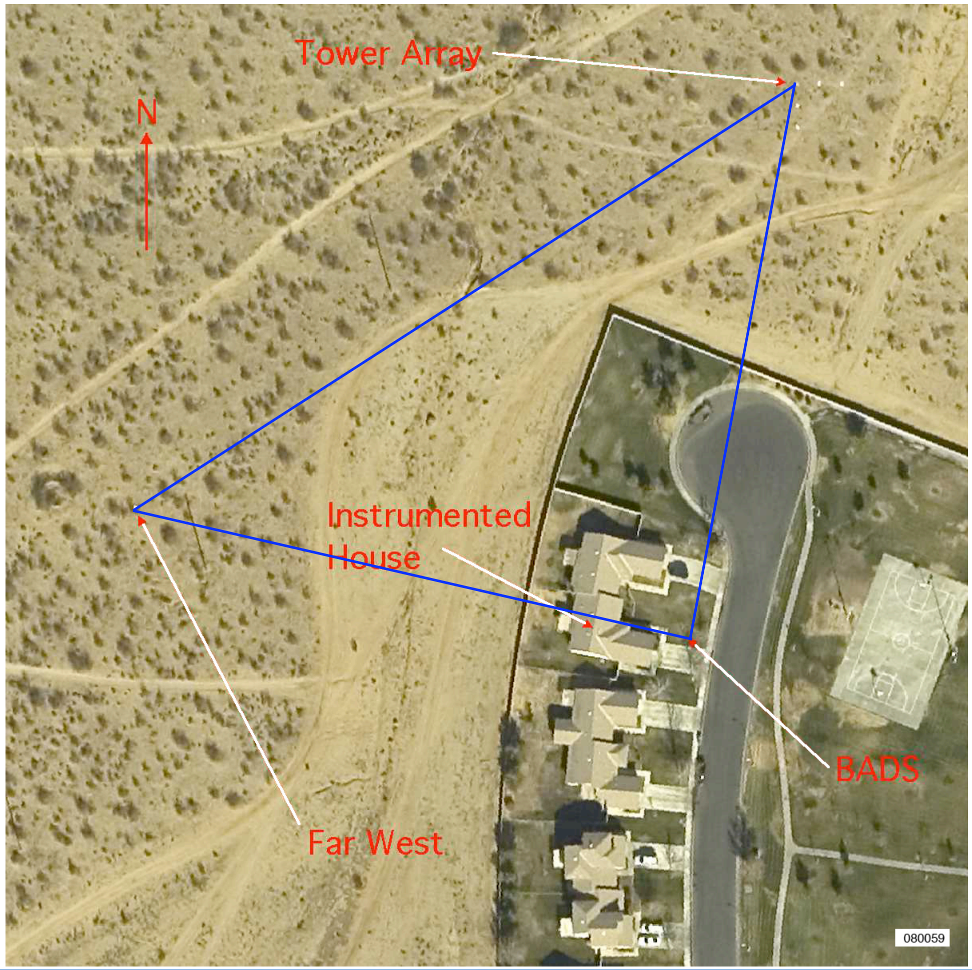
Boom Amplitude and Direction Sensor, BADS

- Six pressure transducers on octahedron truss, about 1.8m on a side
- Automatic recording for all but quietest booms
- Sample rate of 8,333 sps
- GPS time-tagging

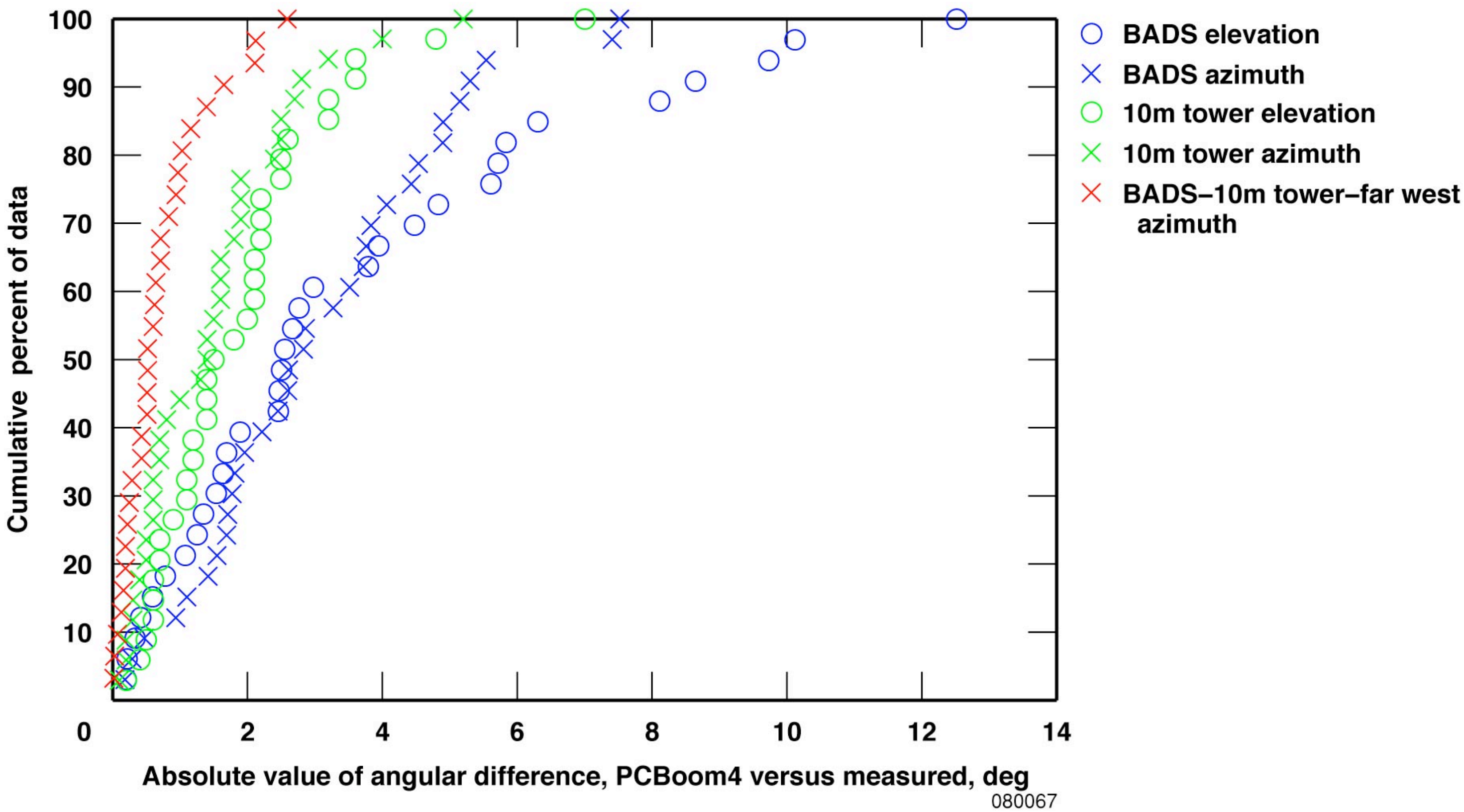
Large Triple Array

- **10m tower, Far West, and BADS sensor used for azimuth**
- **About 130m on a side**



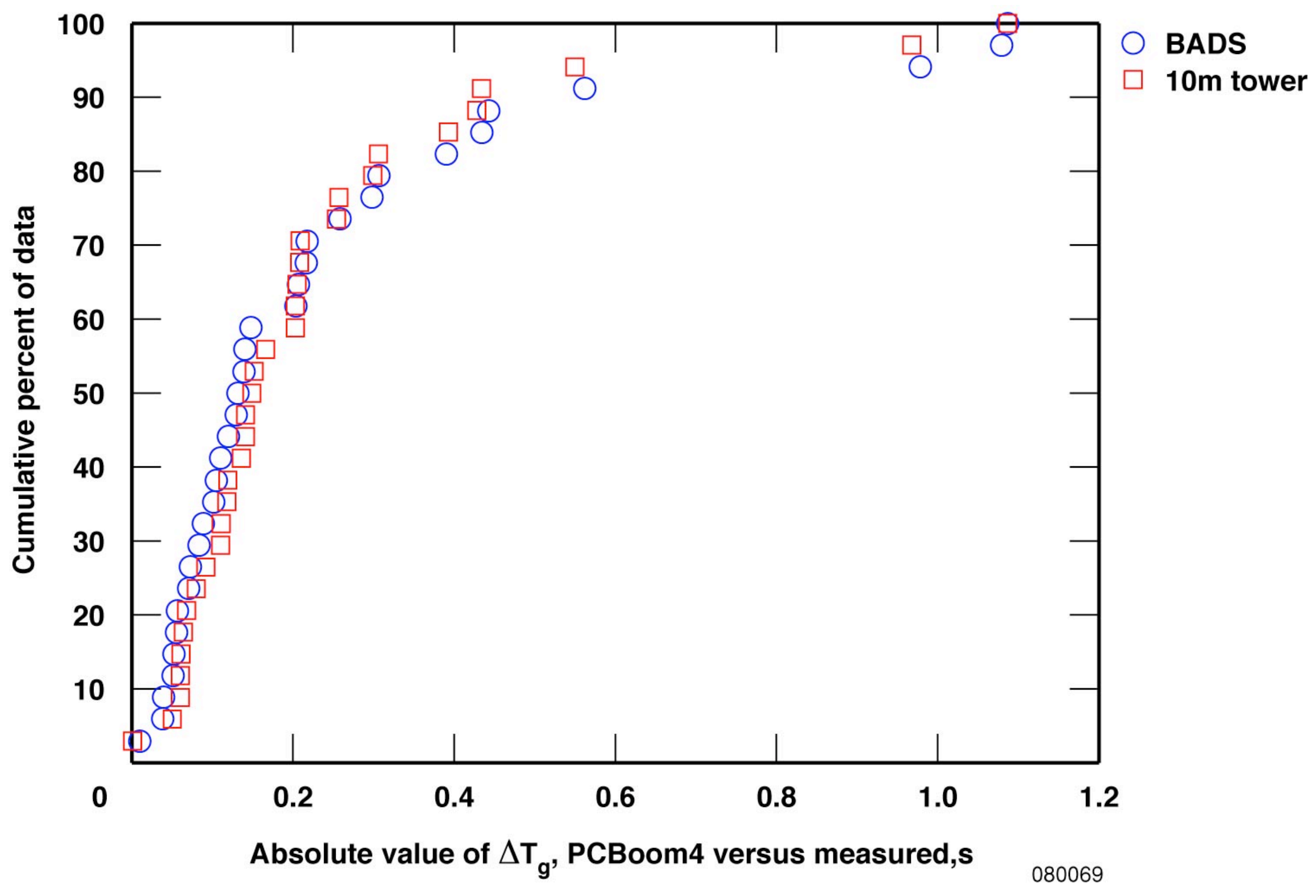
Shockwave Angular Difference, PCBoom4 vs. Measured

- 50% of boom measurements agreed with PCBoom4 to within:
  - 2.6° for BADS, 1.5° for 10m Tower, 0.6° for Large Triple
- Larger arrays give better agreement
- Azimuth agreement better than elevation
- Elevation measurement can be depressed by ~1° due to shock reflection



Shockwave Arrival Time Difference, PCBoom4 vs. Measured

- Arrival times agree within:
  - 0.22 s 70% of the time
  - 1.1 s for all signatures



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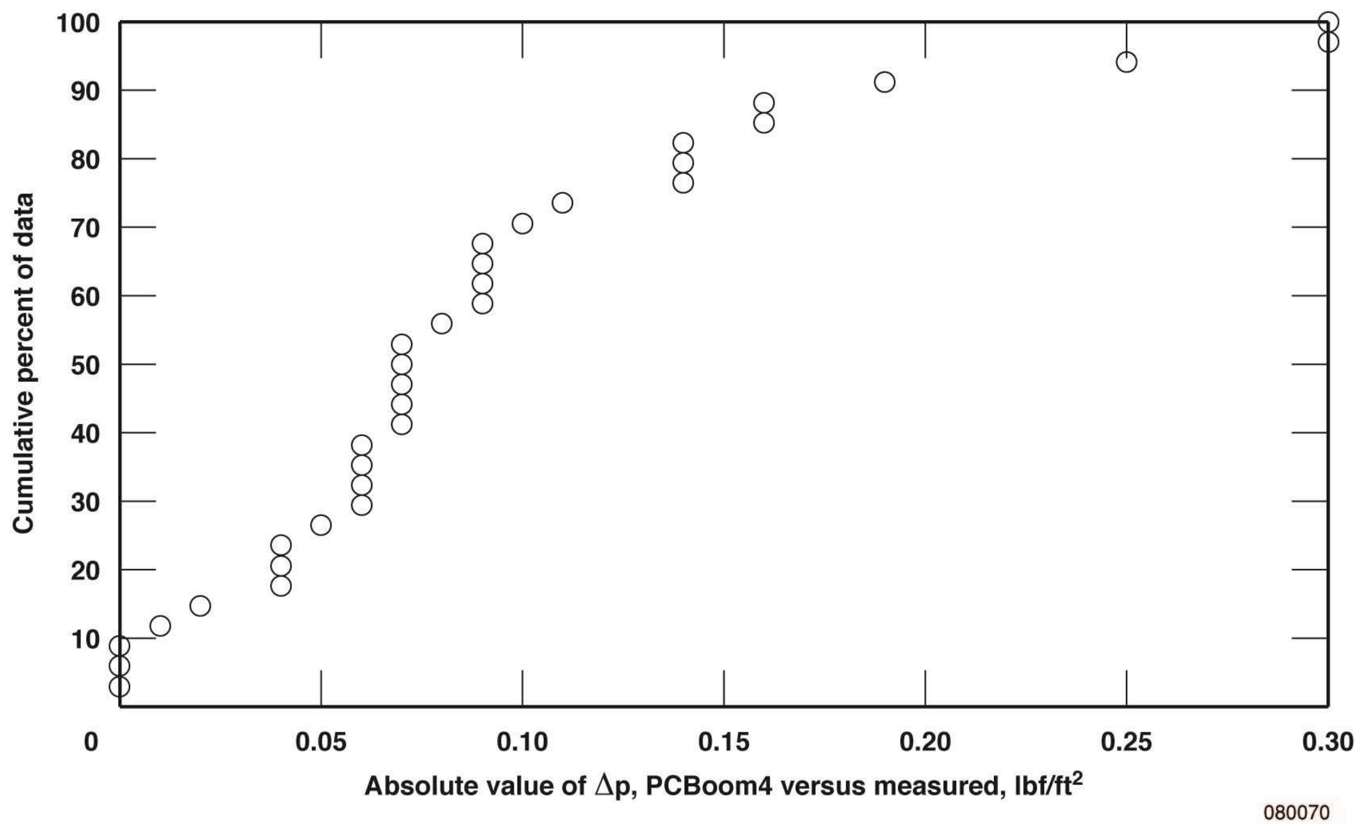
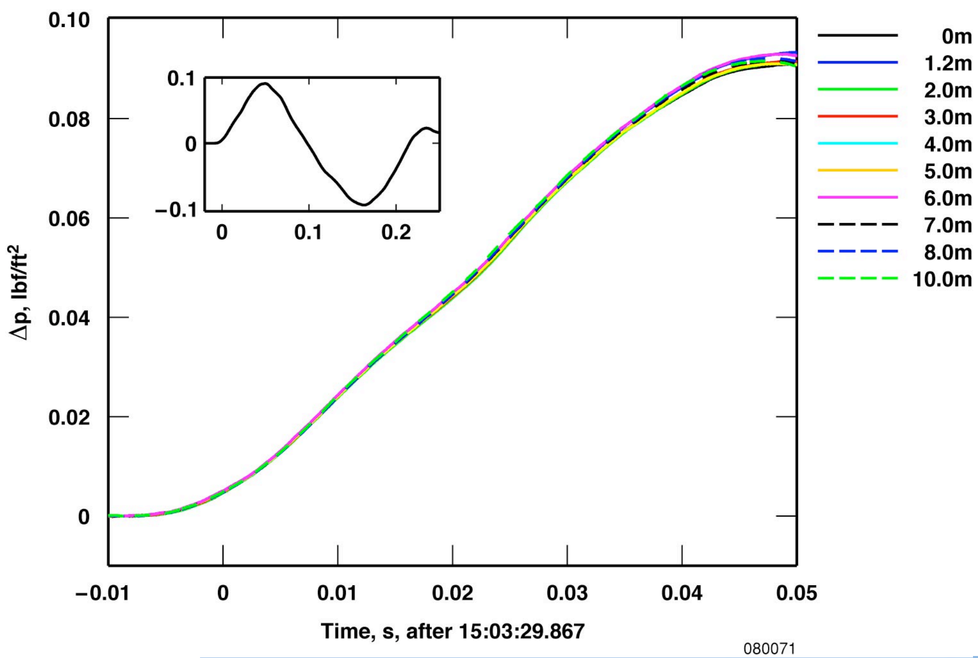
Overpressure Difference, PCBoom4 vs. Measured

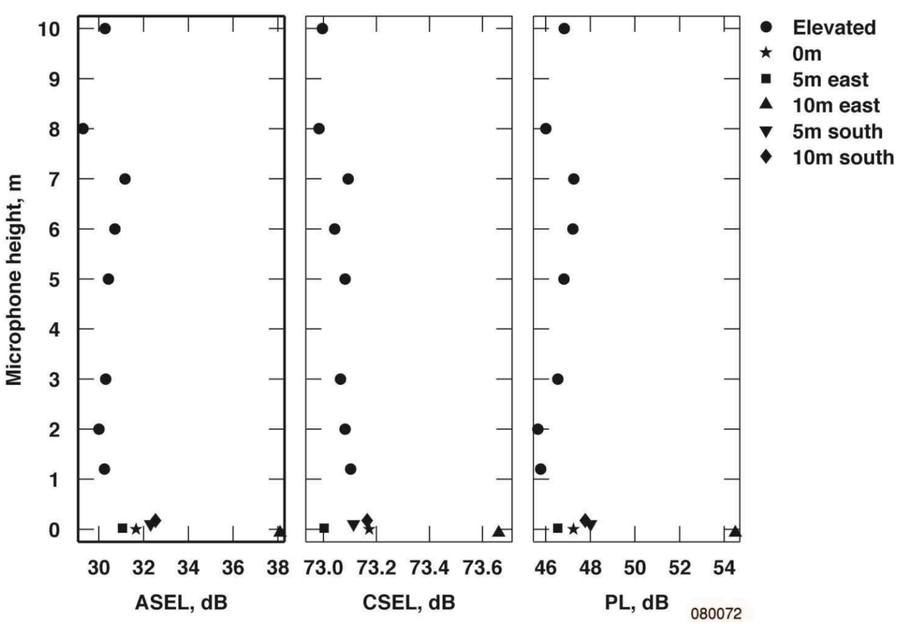
- Measured N-waves were idealized to remove turbulence effects
- Agreement to within:
  - 0.1 lbf/ft^2 70% of the time
  - 0.3 lbf/ft^2 for all signatures



Evanescent Wave (1083P1)

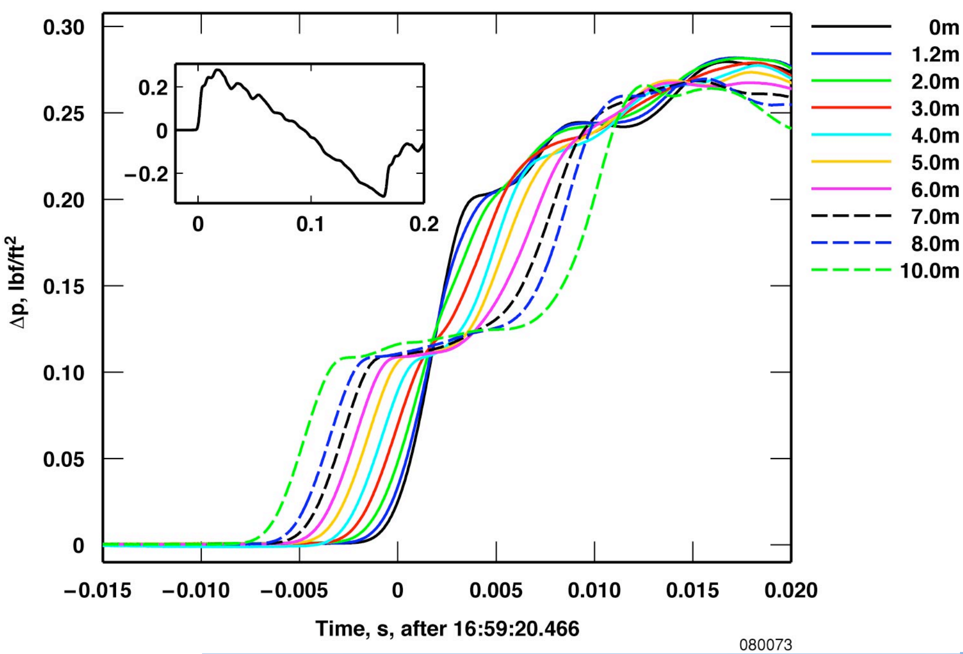
- Signature nearly a sinusoid
- Very low overpressures and elevation angles
- No reflection effect
- Little change in acoustic level with height above ground

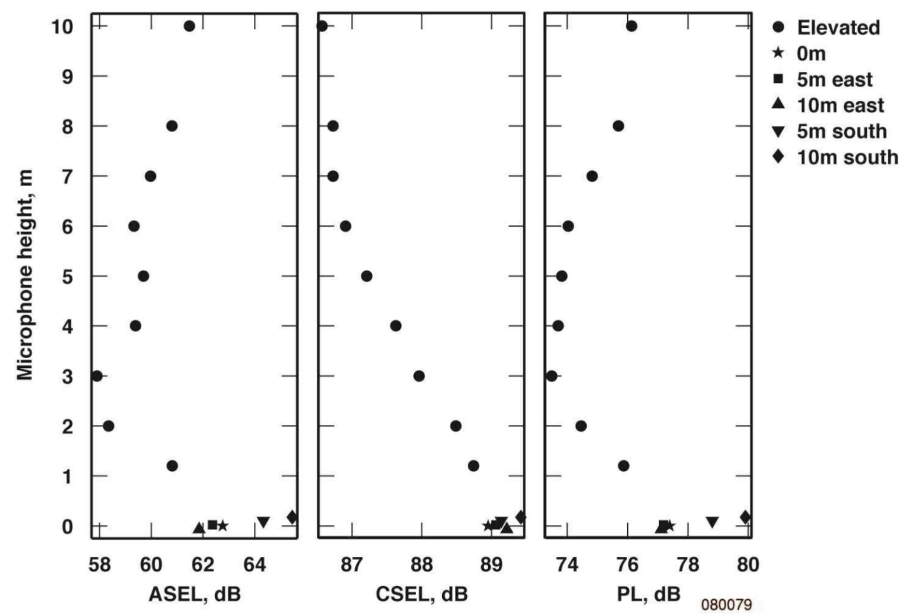




Low Boom, 1 of 5 (1557P4)

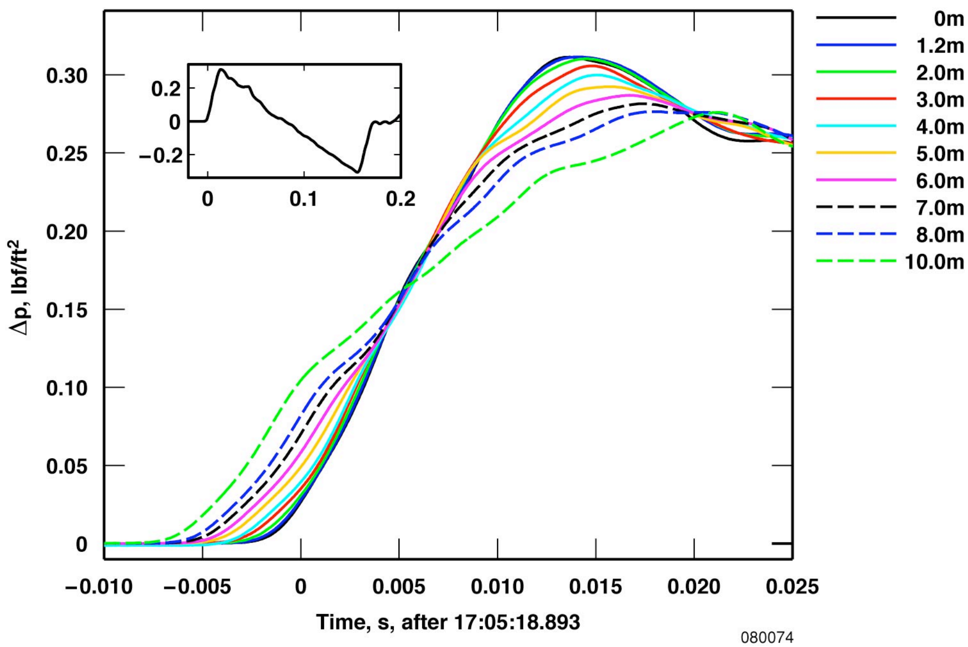
- Signatures at 1.2m and 2m have merged with ground signature
- Signatures above 3m have delay halfway up shock
- Minimum ASEL and PL at 3m
- CSEL decreases with increasing height

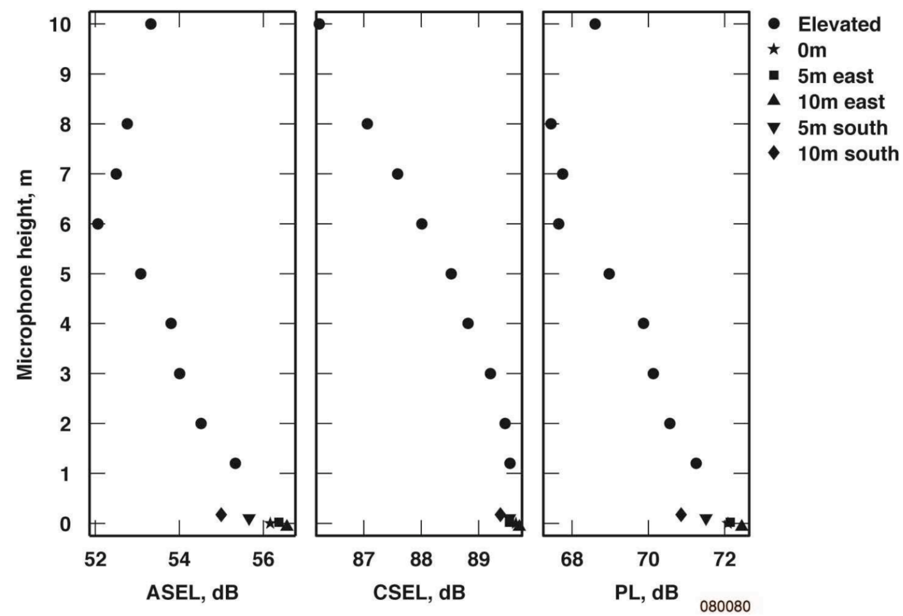




Low Boom, 2 of 5 (1557P5)

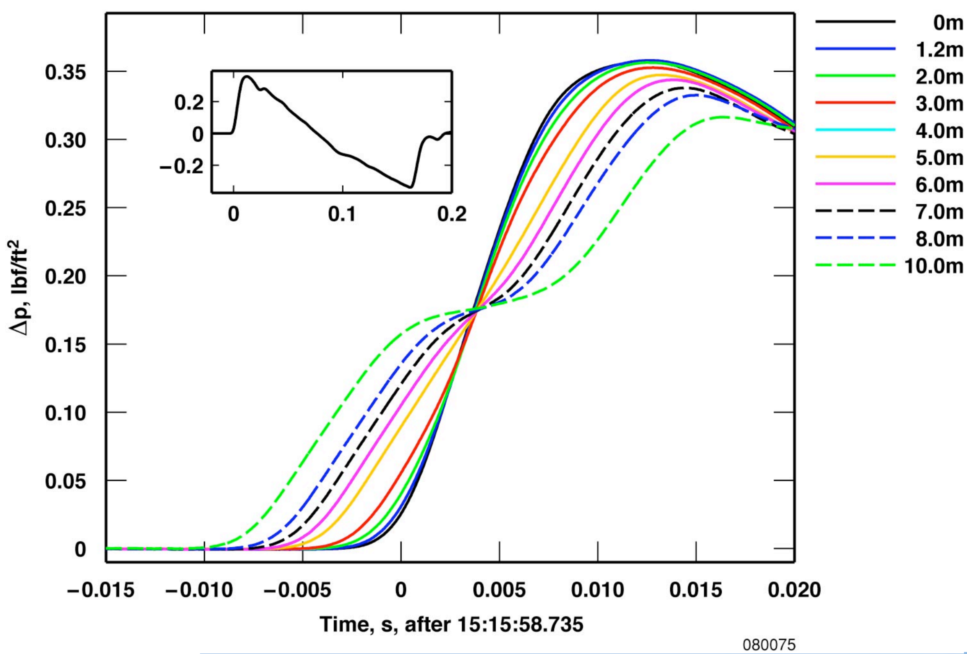
- Signatures below 6m are more merged with ground signature
- Slight delay at higher heights
- Minimum ASEL at 6m, minimum PL at 6 to 8m
- CSEL decreases with increasing height

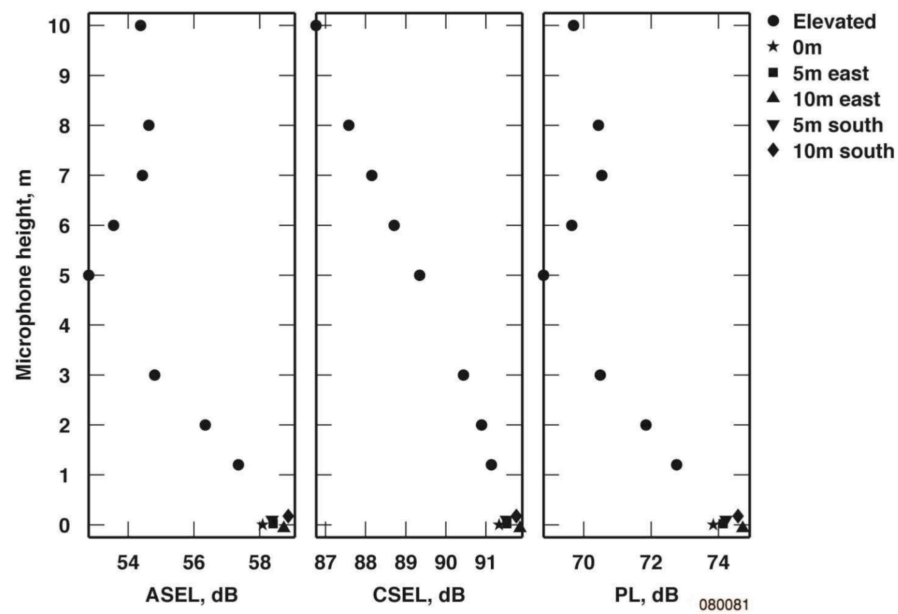




Low Boom, 3 of 5 (1083P3)

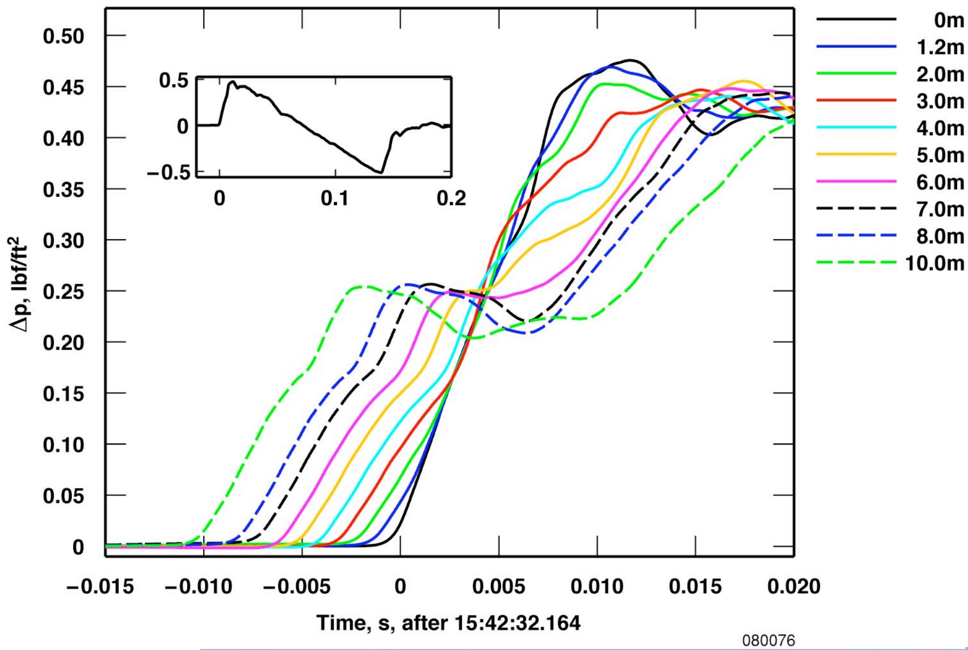
- Signatures below 5m are merged with ground signature
- Signatures above 5m have increasing delay
- Minimum ASEL and PL at 5m
- CSEL decreases with increasing height

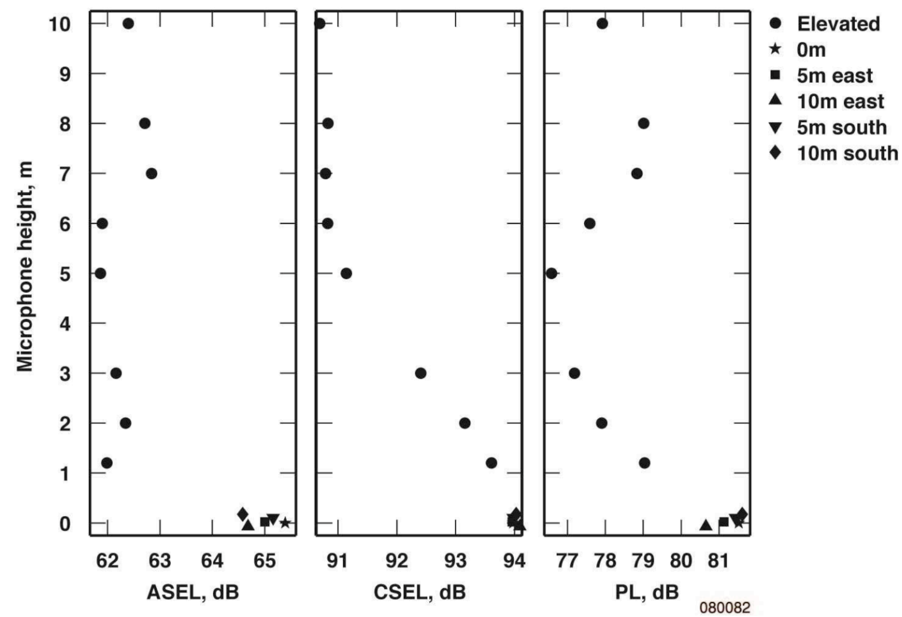




Low Boom, 4 of 5 (1085P6)

- Signatures below 5m have merged with ground signature
- Signatures above 5m have increasing delay
- Minimum ASEL and PL at 5m
- CSEL decreases or is constant with increasing height





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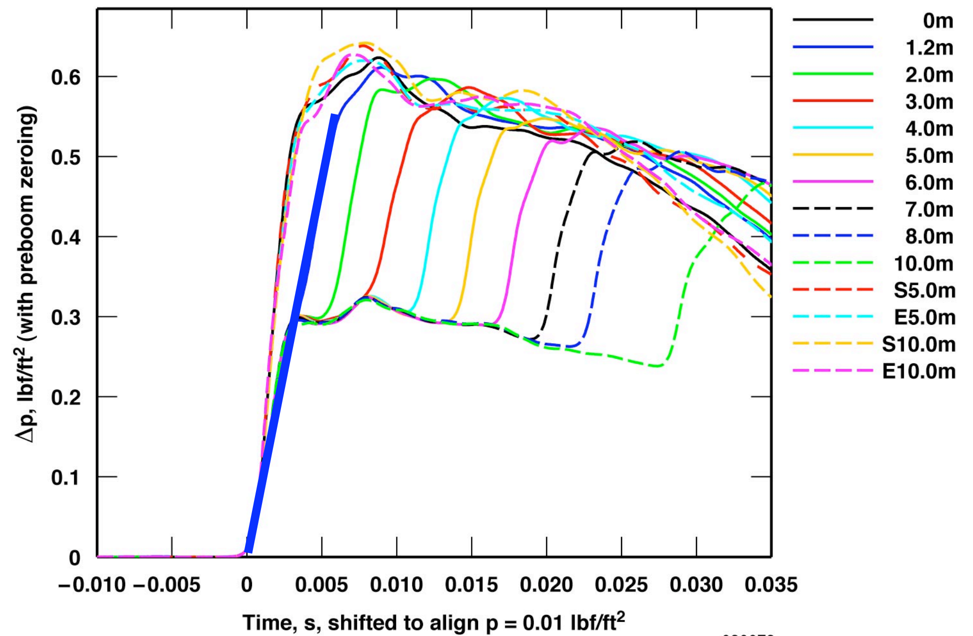
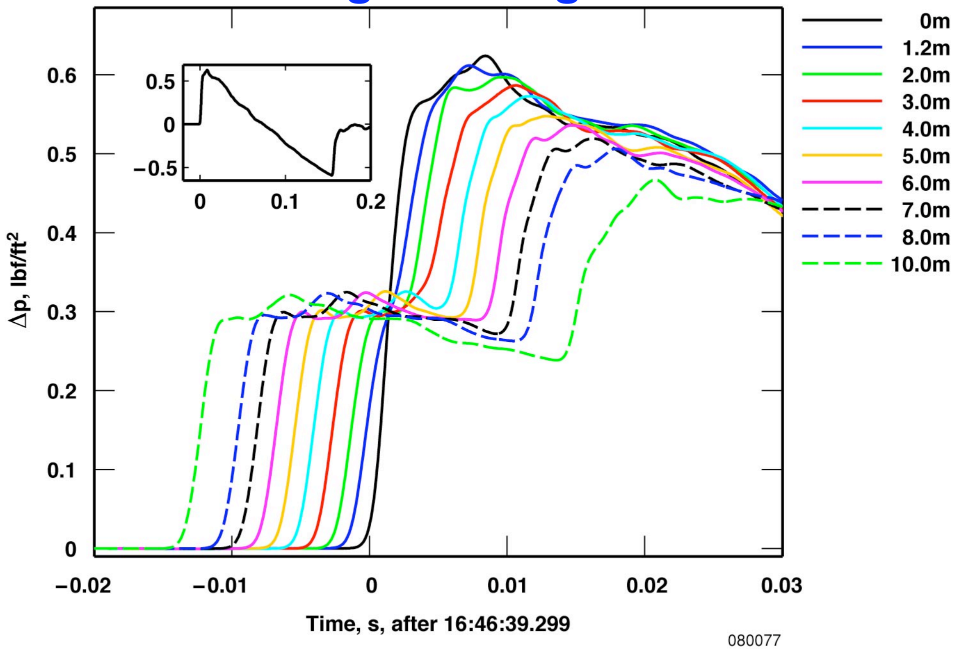
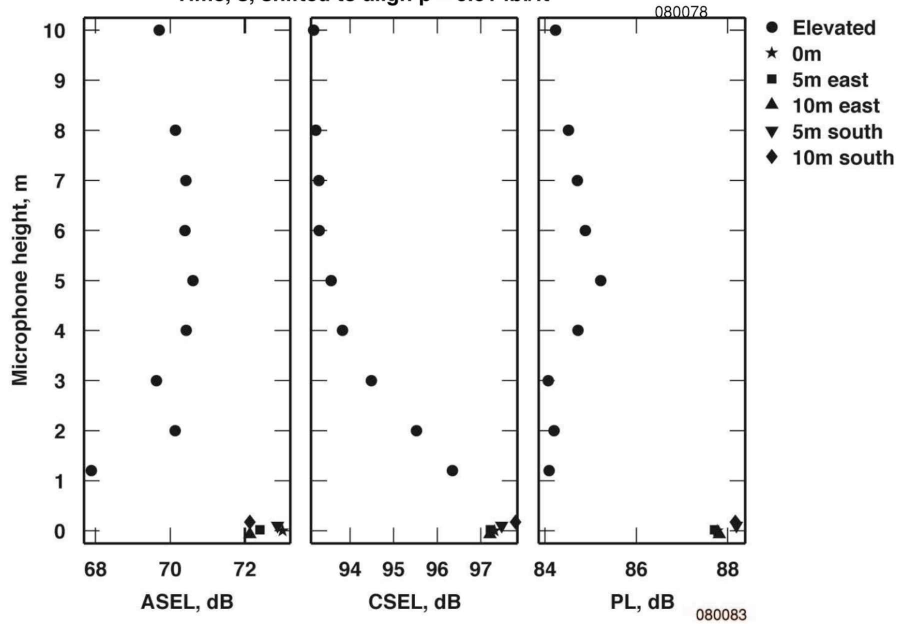
Low Boom, 5 of 5 (1557P2)

- **CSEL decreases or is constant with increasing height**
- **Minimum ASEL and PL at 1.2m**
- **Higher signatures have increasing delay**
- **Minima in ASEL and PL occur where elevated time history of the shock is the straightest, and not merged with ground trace**







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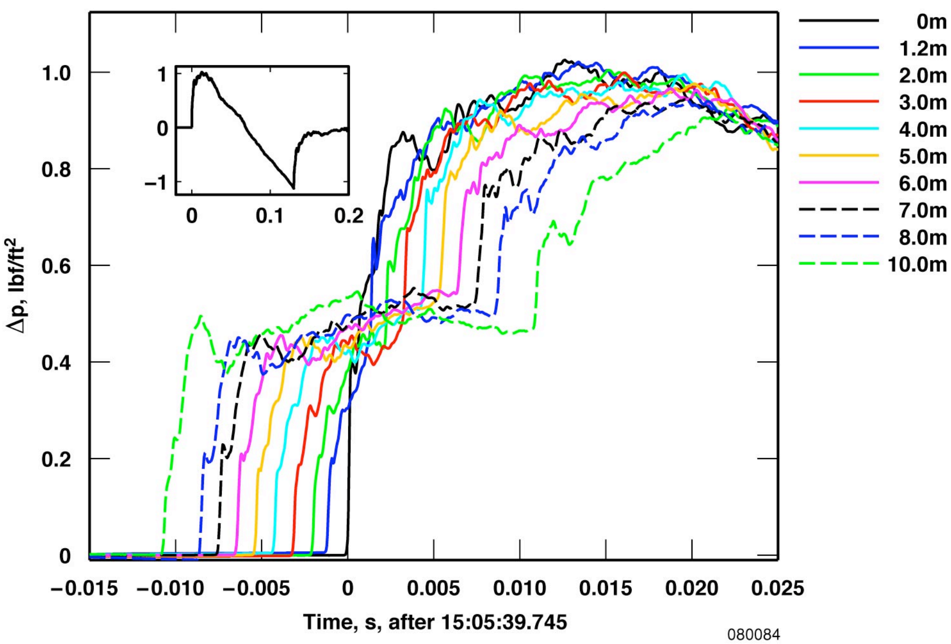
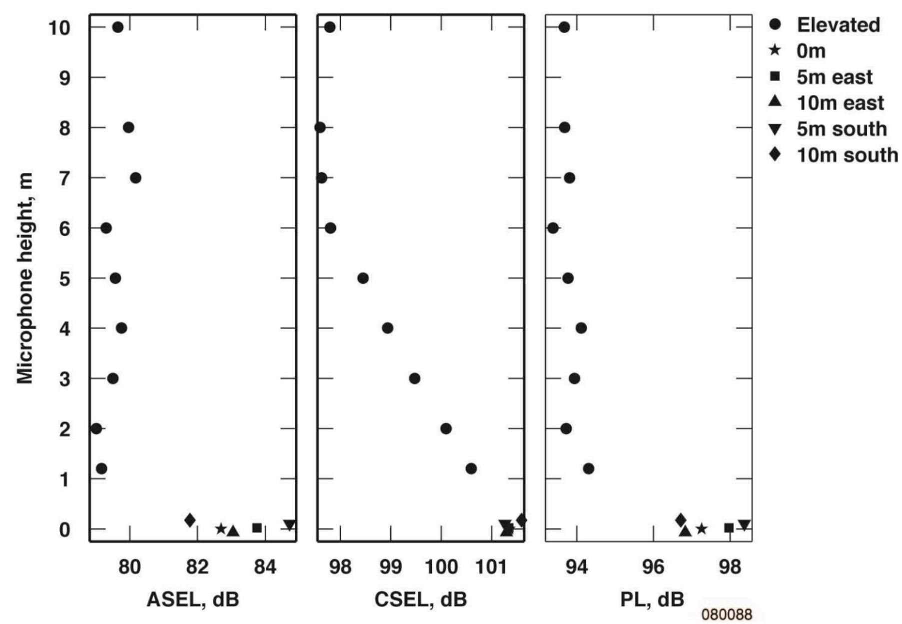
Normal Boom, 1 of 3 (1087P1)

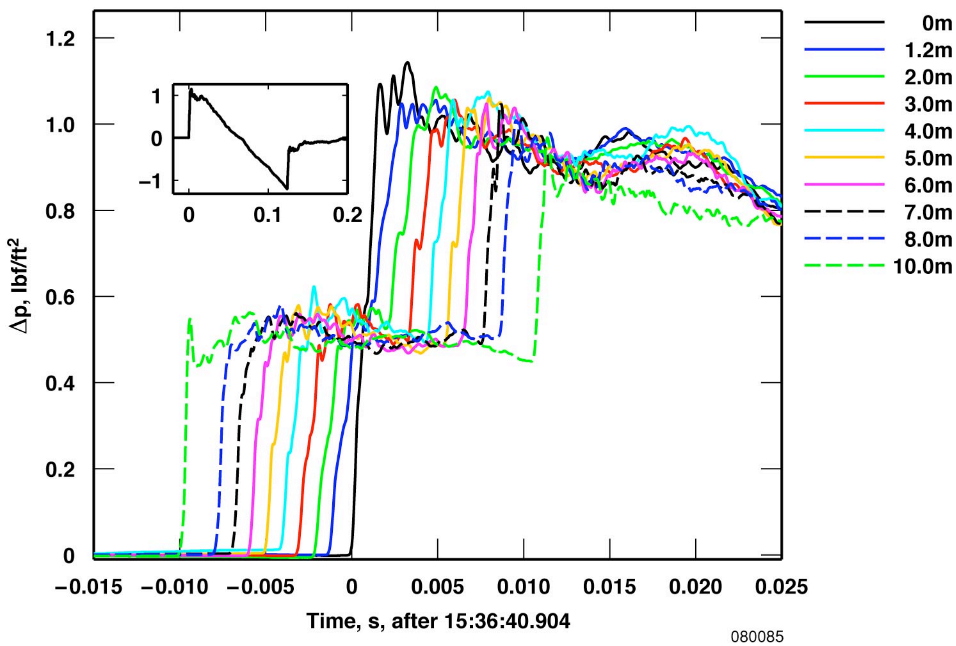
- CSEL decreases or is constant with increasing height
- ASEL and PL do not have minimum at straightest pressure rise, but the signatures strongly show the effects of turbulence

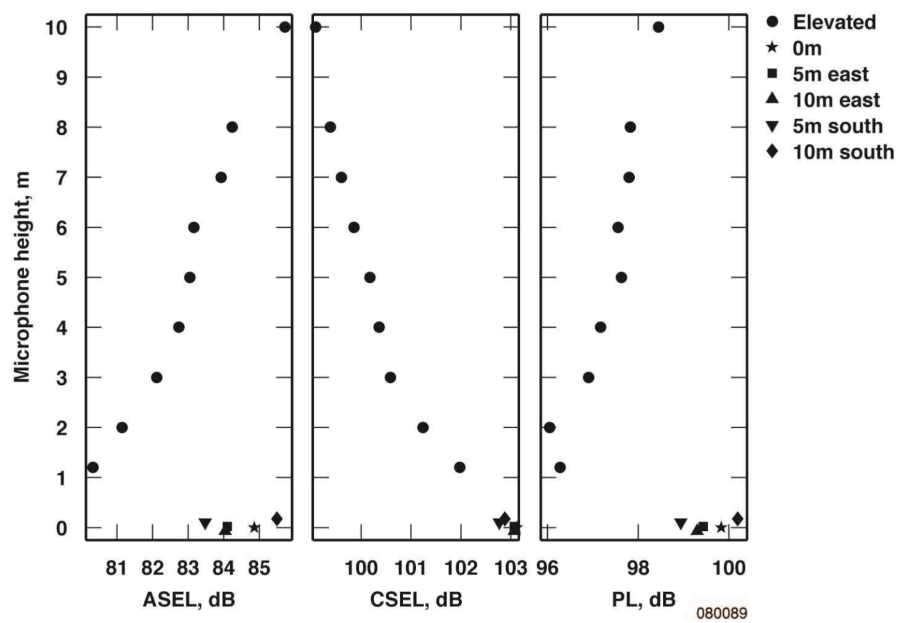




Normal Boom, 2 of 3 (1087P6)

- CSEL decreases with increasing height
- ASEL is minim at 1.2m height, and PL is minimum at 2m height
- Straightest pressure rise occurs at 1.2m





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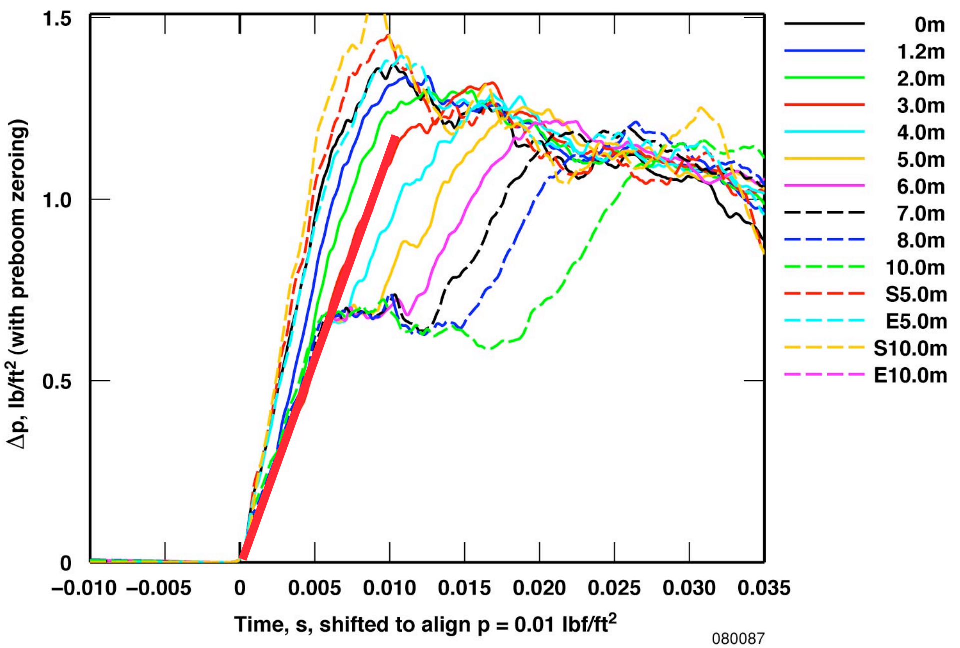
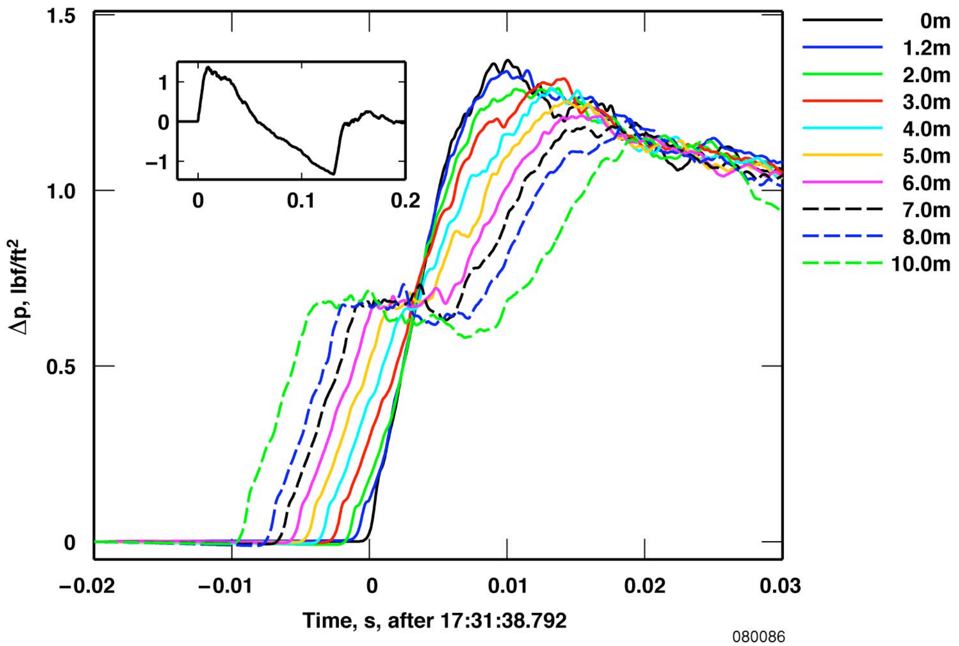
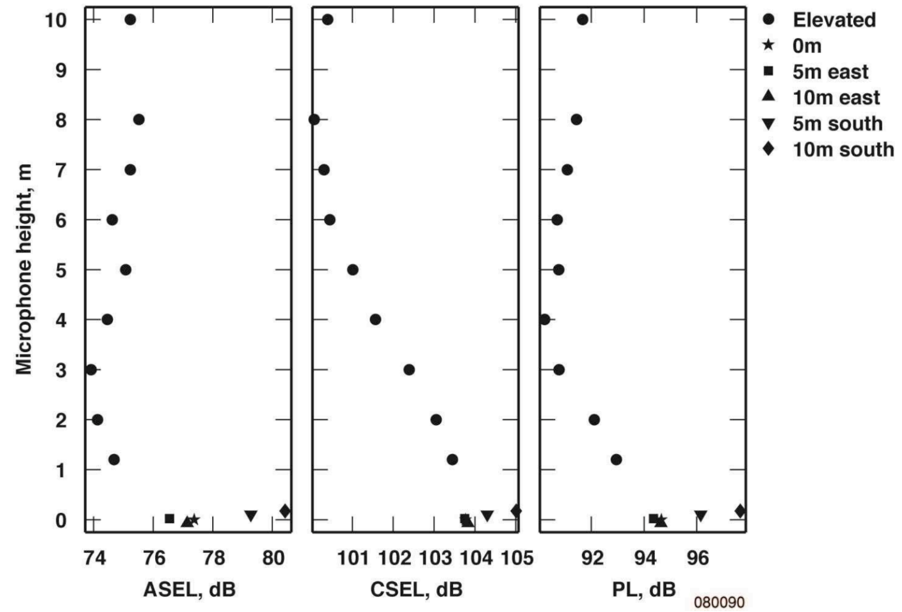
Normal Boom, 3 of 3 (1086P1)

- CSEL generally decreases with increasing height
- ASEL minimum at 3m, PL minimum at 4m
- Straightest pressure rise at 3m

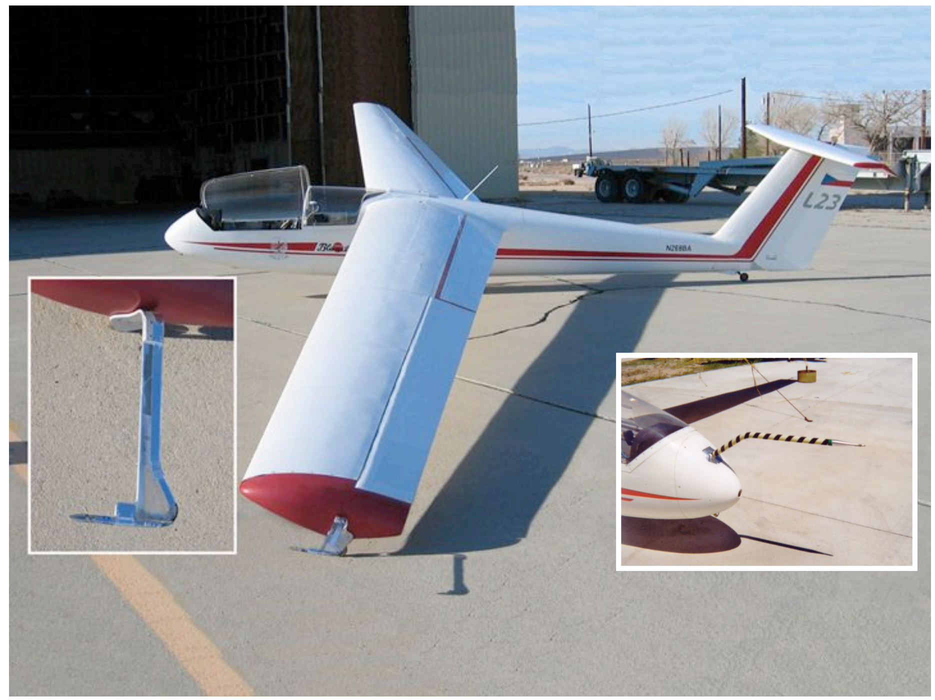






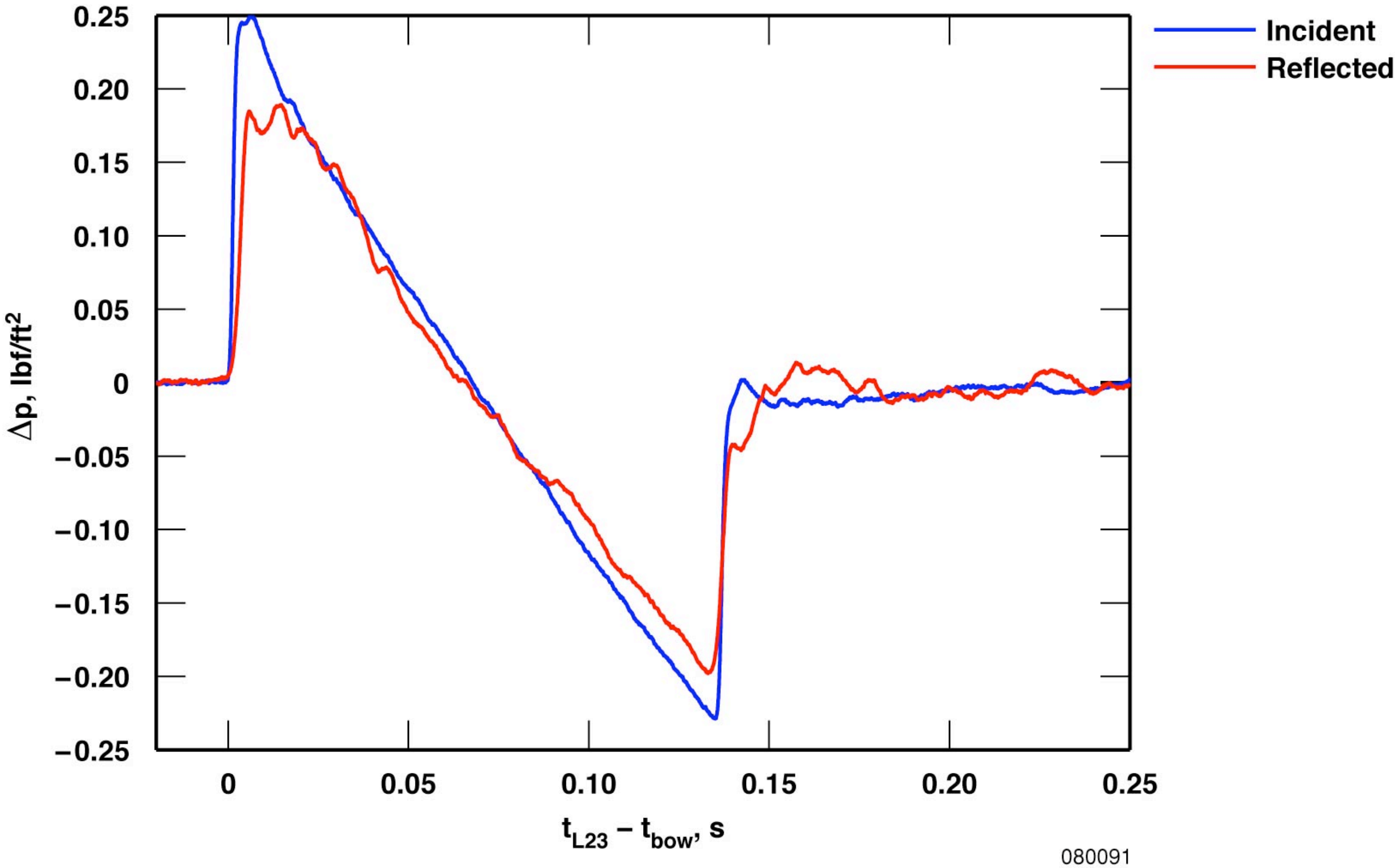
Sailplane

- US Air Force Test Pilot School’s Super-Blanik L-23
- Microphones on noseboom and wingtip
- Same recording hardware as on 10m tower
- Data between 4,000 and 11,000 ft MSL (ground about 2,400 ft MSL)



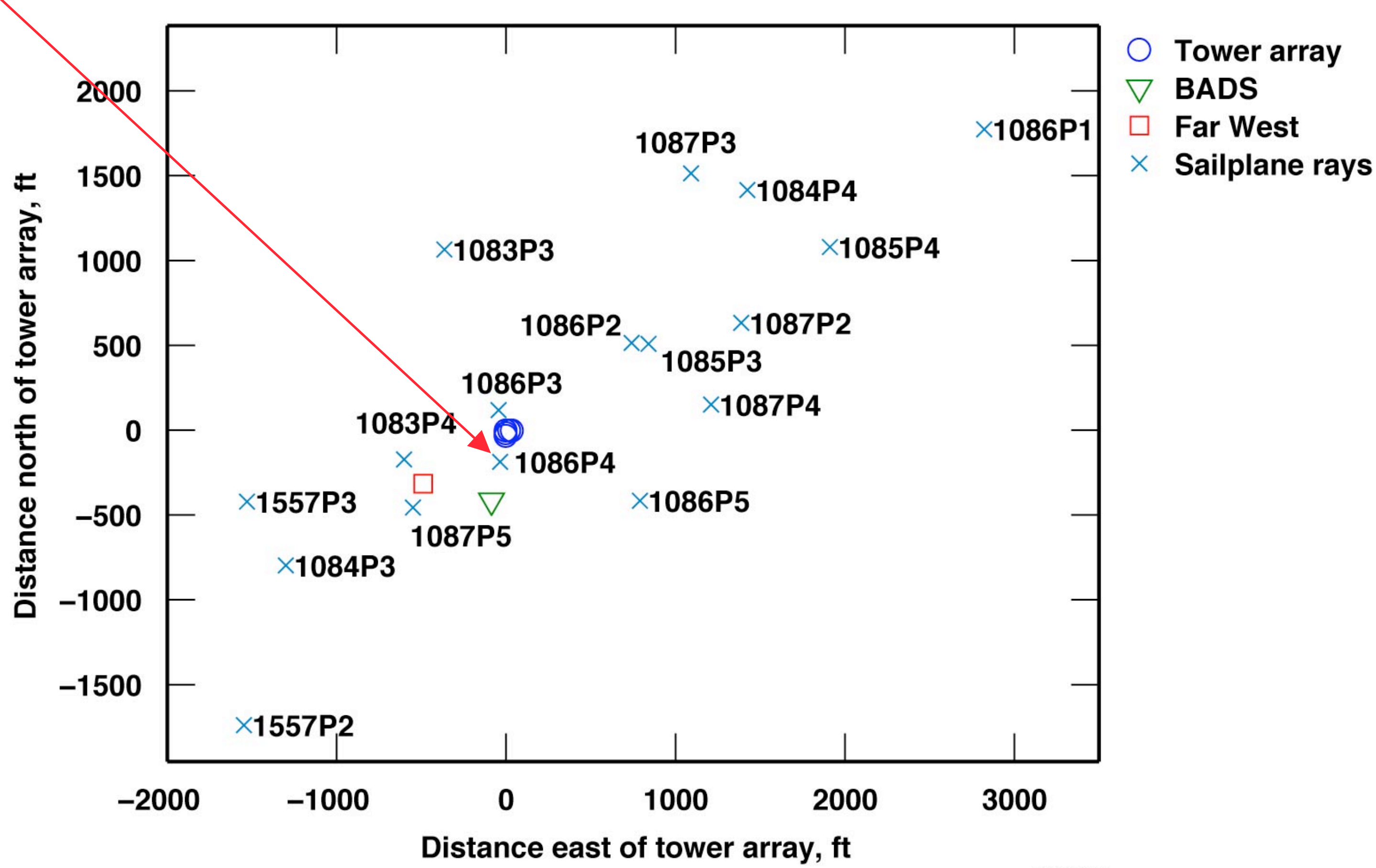
Sailplane Measurements (1085P2)

- Incident and reflected shocks measured
- More turbulence effects on reflected shock
- Quality from noseboom microphone rivals ground measurement



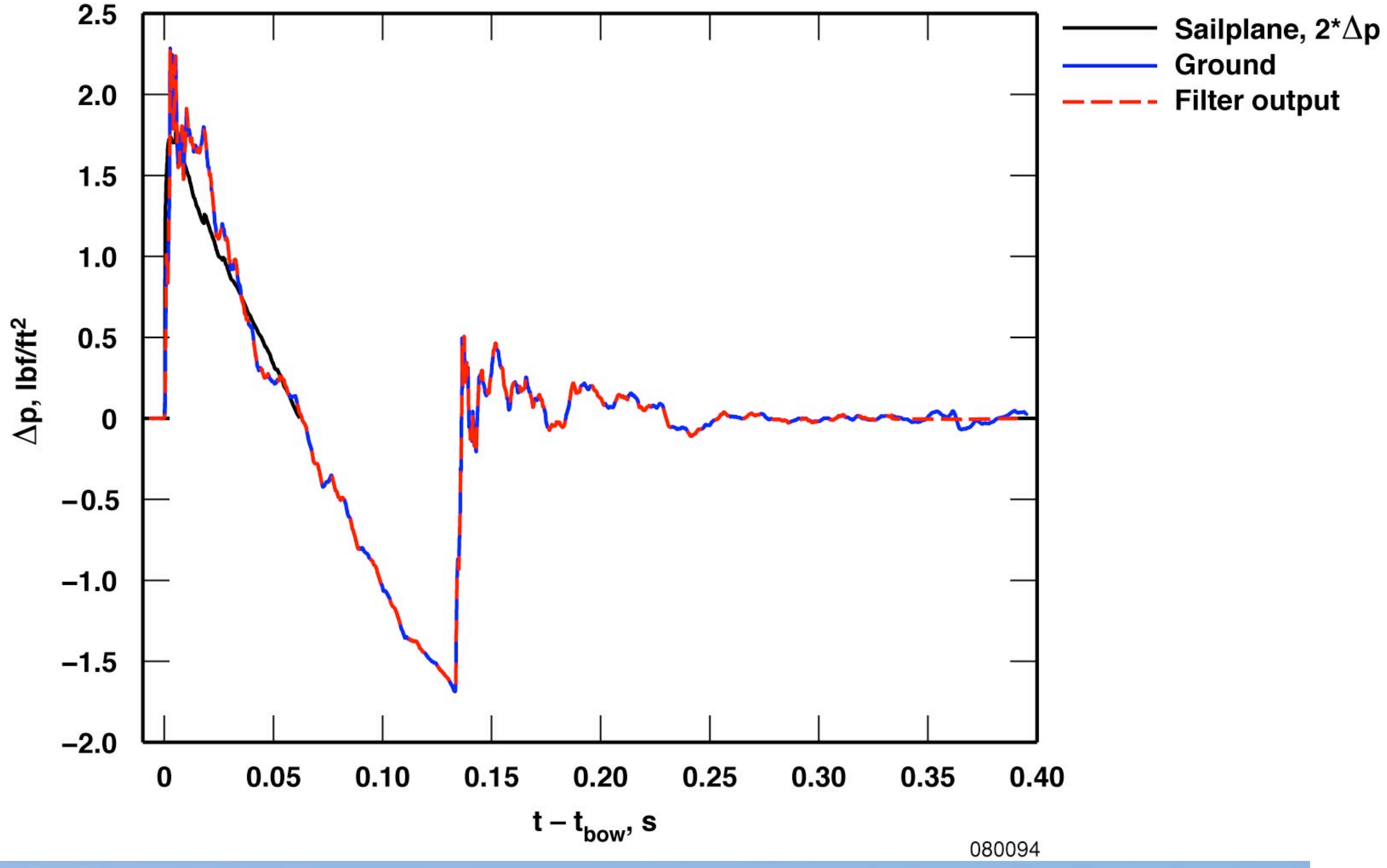
Sailplane Raypath Ground Impact Locations

- Sailplane maneuvered to intercept shock wave that would reach ground microphone
- Several saiplane raypaths within a few hundred feet of ground sensor
- Used sailplane/ground recording pairs to generate turbulence filters



Turbulence Filter Function (1086P4, 0m at tower)

- Only used positive pressure portion from sailplane measurement
- Excellent agreement with ground measurement
- Can be used on "clean" waveforms to induce realistic atmospheric turbulence effects



Concluding Remarks

- Extensive sonic boom database with low- to normal-intensity booms gathered
- PCBoom4 used as effective tool to place desired booms at a specific location, and to guide a sailplane to intercept shockwaves
- Good agreement in arrival time and overpressure
- Shockwave elevation and azimuth angles can be determined with an array of microphones
  - Measured angles agreed well with PCBoom4
  - Larger arrays gave better agreement
  - Equal or better agreement in azimuth than elevation
- Evanescent waves showed little dependence on height
- Elevated microphones show effect of reflection
- CSEL almost always decreases or is constant as height increases
- ASEL and PL have minimums at 1.2m to 6m where elevated microphone shock signature is the straightest
- Sailplane measurement quality on par with ground measurements
- Some sailplane / ground recording shockwave raypaths within a few hundred ft
- Turbulence filter functions generated, showing excellent agreement with ground recordings